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Integrating Greenhouse gases (GHG) assessment for low carbon economy path: Live case study of Indian national oil company

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ABSTRACT

Physical, Regulatory and Brand value risks due to climate change challenges are foreseen by businesses globally. This paper is oriented towards these challenges and prepared a comprehensive Greenhouse gases (GHG) footprint plan and identification of mitigation opportunities for ONGC, a fortune 500 and national oil company of India. Internationally recognized standards and guidelines like Greenhouse Gas Protocol, ISO-14064, and American Petroleum Institute compendium have been referred for quantifying carbon emissions in nearly real 400 + operation control facilities. The GHG inventory is based on Operational Control approach to identify the boundary for which emissions are to be quantified and two significant scopes of emissions viz Direct Emissions and Indirect Emissions are identified and quantified. The quantification concluded that GHG emission footprint for the year 2016–17 is in the range of 9 million tons of CO_2equivalent. GHG emissions mainly account due to stationary combustion, fugitive emissions and wastewater treatment, which share the around 56% of total emissions. Another 24–26% of emissions are contributed due to flaring, processes by glycol dehydrator, acid gas removal units, and by electricity purchased from the grid. As a result, it has been found that ONGC emits 187 kg CO_2e emissions per tonne throughput and also compared with its global peer organizations. At the organization level, "Key Industrial Sites" have been identified as contributing higher GHG emissions and accordingly key "hot-spots," a list of 15 GHG mitigation opportunities have been proposed in the paper. Two GHG mitigation initiatives based on solar energy and bioenergy application undertaken at ONGC has also been briefed on case studies.

1. Introduction

The journey of climate change has graduated tremendously, scientists, government, and policymakers have agreed that it is an outcome of anthropogenic activities. These activities are mainly due to fossil fuels and increasing the concentration levels of Greenhouse gases (GHG) in the atmosphere. Further, the Carbon Dioxide (CO_2) concentration has risen to 380 ppm (parts per million) as compared to the concentration level of 280 ppm before the industrial revolution. This 40% significant rise in CO_2 concentration are unequaled for the past 800,000 years (Change, 2010; Hughes et al., 2018). Intergovernmental Panel on Climate Change (IPCC), in its 3rd assessment report predicts that the earth's mean temperature is expected to increase from anywhere between 1.5 and 5.4 °C by the year 2100, depending on the amount of GHGs emitted and the response of climate to this rise (Houghton et al., 2001).

Recognizing the associated risks, global entities have been acting to build in greater resilience to climate change impedance. In parallel, many countries have formulated unilateral policies and programs that help reduce or avoid GHG emissions. Some have been explicitly undertaken to address climate change, and others are driven by economic, energy, or development objectives, with the active contribution to climate efforts (Ramachandra et al., 2015). The potential of GHGs have also been studied based on their emission costs, and quantification of GHG's liability has been estimated in the range of $570 trillion (Heidari and Pearce, 2016). This quantification suggests that humankind shall bear this liability towards carbon mitigation and be taken care off by the deployment

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of Renewable Energy (RE) technologies. The oil and gas (O&G) sector have been continuously impacting global economy due to intense energy demand, however it mirrored the GHG emissions too. O&G related activities contribute around 70% of global GHG emissions mainly through hydrocarbon extraction, processing and subsequent combustion process (API, 2009). However, along with GHG reduction pledge, many countries are facing significant challenges while maintaining their economic prosperity.

In a particular case study, Thailand has adopted the low carbon economy path and examined the role of O&G industries towards the energy mix transition (Chaiyapa et al., 2017). It has been found that the voluntary national guidelines and mandatory regulations are major drivers for better environmental sustainability. Also, the proactive response towards climate change mitigation has shown the significant degree of oil sector commitment. Fiscal incentives have also been one of the key drivers for low carbon strategy. The long run investment on energy transformation based on government regulations and brand image of the companies. The study of Thailand green energy system encouraged more exhaustive evaluation for various global O&G industries.

Globally O&G companies have been trying to progress further with their leadership position and managing the climate change mitigation impacts. It has become so crucial for organizations world over, that creating a detailed plan for risk assessment & mitigation opportunities identification is a must. Accordingly, key drivers which make this GHG assessment essential have been identified (Weyant, 2017).

The Indian government's National Action Plan on Climate Change (NAPCC) has identified eightfold national missions, focused on mitigation of GHG emissions and adaptation to climate change effects (Chandel et al., 2016). The impact of this mission has been reflected in Indian industry through reduced GHG emission intensity around 17.6% in between the year 1990 and 2005. Additionally, Department of Public Enterprises (DPE) Government of India has issued guiding compliance on the Sustainable Development (SD) and Corporate Social Responsibility (CSR) for all public sector units in the country (Oberoi, 2014).

ONGC (www.ongcindia.com), a Fortune 500 company, is the leading national oil company under Ministry of Petroleum and Natural Gas, Government of India. As a response to national mission policies, four key driver mechanism systems have been evolved to quantify the emission contribution within operational boundaries as shown in Fig. 1. Multi-functional process installations of pan ONGC has been covered for consolidated inventory process. The primary emission sources have been identified and classified as direct emissions and indirect emissions.

Basic rules and guidelines for the GHG inventory have been taken in accordance with the requirements of International Standards Organization (ISO)-14064 and the Greenhouse Gas Protocol (Schmitz et al., 2004). Technical guidance for quantifying emissions from sources specific to O&G sector operations has been taken from the American Petroleum Institute (API) compendium (API, 2009). Emissions of all six gases in Kyoto basket of GHGs has been targeted and quantified. The quantification has been made based on weighted average of CO_2 equivalent.

The operational control approach has been used for the GHG inventory and followed the global standards protocols. General practice for the GHG assessment includes the organizational operational boundaries, available standard methods for emissions calculations, data collection and deriving emission factors. The baseline GHG assessment needs to be identified for real field site data and opportunities for the reduction of the emissions. The comprehensive GHG assessment predicts the 'hot-spots" within the organization for targeted future activities and demonstration.

This paper summarises the GHG emission assessment concept, adopted methodology live case studies, results, and future action plan for pan ONGC industrial sites. The article has been prepared with literature references of World Resource Institute (WRI) and World Business Council for Sustainable Development (WBCSD) GHG protocol (Schmitz et al., 2004). It has been estimated that the emission quantification or GHG assessment for the ONGC is around Nine Million tonnes of CO_2 equivalent for the year 2017 and finally compared with emission intensity profiles of global peer organizations and competitors.

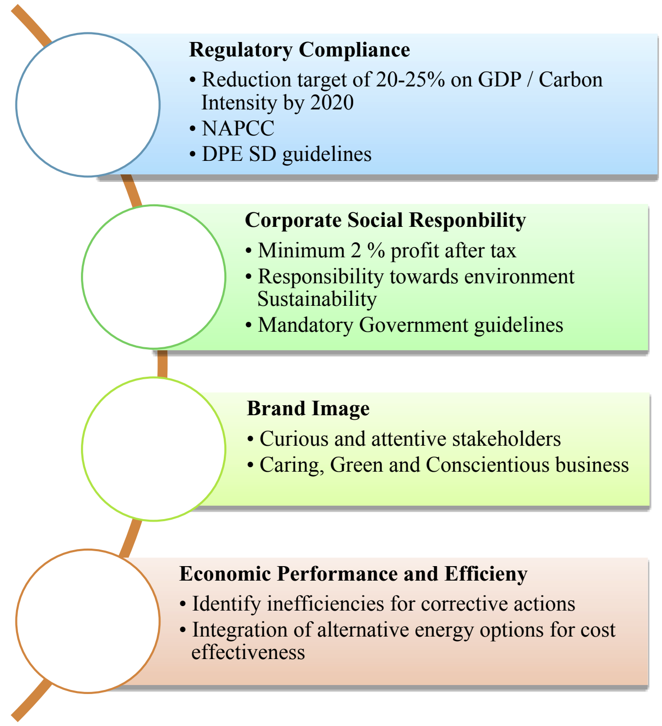


Fig. 1. Four key drivers for GHG accounting used for Indian Sector.

Active utilisation of Renewable Energy (RE) resources has been identified as one of the mitigation methods for GHG reduction. Accordingly, two feasible and sustainable method case studies, first on utilising Concentrated Solar Power (CSP) for crude oil heating purpose and bio-fixation of the industrial vent through Microalgae have been briefed. Finally, it has been concluded that GHG assessment has provided ONGC a roadmap for the energy transformation and gradual shift to green electricity and making Exploration and Production (E&P) organization as new 'Energy Company.'

2. Corporate GHG mapping and methodology

India took the challenges to contribute voluntary to reduce the carbon emissions. ONGC an environment and socially responsible corporate has taken up several mandatory policies towards GHG emissions mitigation. The aspirational goal of carbon management starts from the measurement and assess the carbon footprint.

2.1. Conceptual thoughts

The term "carbon footprint" or "GHG emission assessment" refers to the total profile of GHG emissions which are being emitted as a result of the activities of an organization. The GHG assessment encompasses a range of emission sources, each having different levels of impact or Global Warming Potential (GWP). The accounting protocols recommends accurate inventory quantification

and ensuring the inclusion of all six GHG (The Greenhouse Gas Protocol, 2005). However, reporting mainly focuses on the emission of CO_2 only, since it has been reported as most significant contributor out of the six GHG.

The GHG-ISO protocol provides the generic guidance for calculating and reporting an organization's carbon footprint whereas the API compendium offers comprehensive methodologies for estimating emissions from the O&G sector activities. GHG accounting and reporting practices are continuously evolving along with evolving knowledge of the science of climate change. Therefore, GHG protocol and ISO-14064 standards require that all updated inventories following the principles as stated in Table 1 (Wintergreen and Delaney, 2006). Various framework and quantification tools for carbon accounting are being continuously revised due to several developments in the recent years (ISO, 2018).

The five-step GHG accounting methodology as shown in Fig. 2 has been defined using inventory principles for any organizational business structure concerning the legal procedure. The corporate boundary of an organization is determined to identify the parts of an organization's business for which the GHG emissions are to be estimated. The consolidation methodology of emissions has been based on individual sites and organizational level. The operational boundary identifies the emission sources inventories as direct or indirect emission sources (Harangozo and Szigeti, 2018).

Next phase, emission calculation methodology need to be finalized. There are some basic concepts behind techniques to calculate emissions in standard cubic meters (SCM) or million standard cubic feet (MMSCF) from an emission source as shown in Fig. 3. Each of the emission calculation techniques has a level of accuracy with selected method and corresponding implication concerning budgeted cost and effort with restriction of data available (API, 2009).

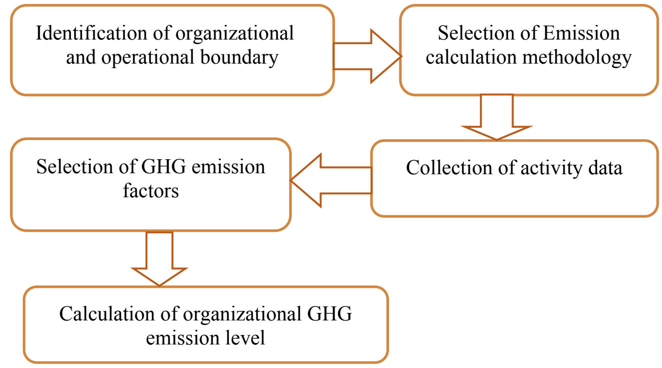


Fig. 2. Five steps GHG accounting methodology.

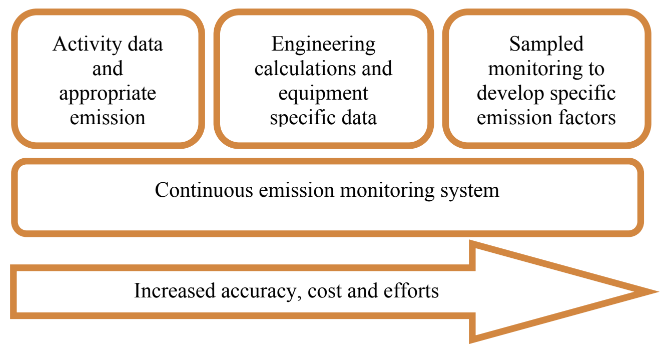


Fig. 3. Techniques to calculate GHG emissions.

2.2. Oil and gas boundary strategy: ONGC

The organizational structure defines the variation in business operations for any corporate. For a consolidate GHG emissions reporting, two distinct approaches have been referred, first the equity share and other with operational control. The equity share accounts for GHG emissions from operations according to its share of equity in action. Under the control approach, a company accounts for 100% of the GHG emissions from its field operations over which it has control either financial control or operational control. GHG protocol and ISO-14064 suggests that, if the reporting company wholly owns and operates all its operations, its organizational boundary will be the same, no matter which consolidation approach is utilized (Huang et al., 2009).

For inventory, operational control approach has been applied which accounts for 100% emissions from facilities over which it has operational control. The comprehensive data collection has been carried out for more than 420 + sites pan India, including process installations and other facilities like GGS, GCP, ETP, CTF, Offshore processing Platform, Offshore/Onshore Drilling Rigs, etc. as shown in Fig. 4.

Emission sources for GHG inventory at ONGC need comprehensive activity data collection and its verification. As classified, direct emissions do occur from sources that owned or operationally controlled by the organization. The purchased energy accounts for indirect emissions are also to be reported for the assessment. There have been some reported additional emissions from the various activities, but not controlled, these are mainly related to contracts or subcontracts and have been referred as third scope, however not included in the assessment. The first two emission categories are mandatory to be reported, however, the third scope category is voluntary with the organization. Segregating emission sources into these two “Scopes” ensures that no two organizations can account for the same emissions in the same scopes, therefore confirming that there is no double counting of emissions. Following ISO-14064 standards, the activities lie under the ownership control and are, therefore, quantified for this inventory has been direct emissions

Table 1
GHG protocol, Guiding Reference and Inventory Principles.

Protocol and Source	Relevance	GHG Inventory Principles
GHG WRI and WBSCD	Provides general guidance for corporate GHG accounting and reporting	1 GHG inventory supports for making informed decisions and making organization business sustainable
ISO 14064-1 International Standards Organization	Organizational GHG quantifying, reporting and verifying using ISO standards	2 Comprehensive and transparent GHG accounting compliance with business boundaries
		3 Ensured GHG accounting. Change in Business boundaries, data and methods suggest new inventory
API Compendium American Petroluem Institute	Provides methodologies for calculating emissions from sources in Oil & Gas operations	4 Exposed to transparent inventory and accounting to regulators and assessor
		5 Sufficiently precise data enable users for reasonable decisions

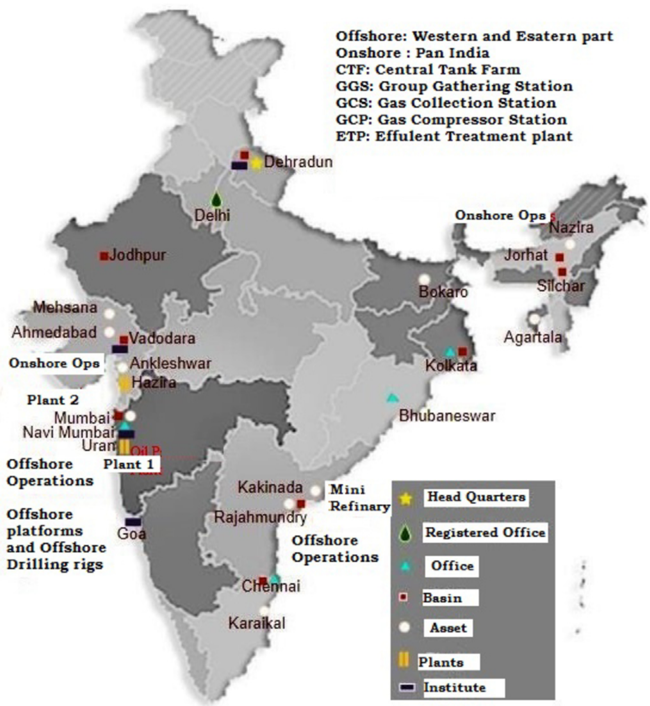


Fig. 4. ONGC pan India operational facilities.

are from combustion sources, fugitive sources and process sources. Fig. 5 and Table 2 describes the emissions classifications being undertaken by ONGC for GHG accounting studies.

Emission factors and calculation methodology are further parameters for corresponding GHG emissions of individual sites (API, 2009). The combined consolidation methodology chosen depending on the method to determine the organizational boundary is to provide GHG emission estimation at the corporate level. Depending on the selected calculation technique as referred in API compendium, activity data on the emission source has been collected as accordance to emission classifications. Activity data have been generally obtained from physical documents like electricity bills,

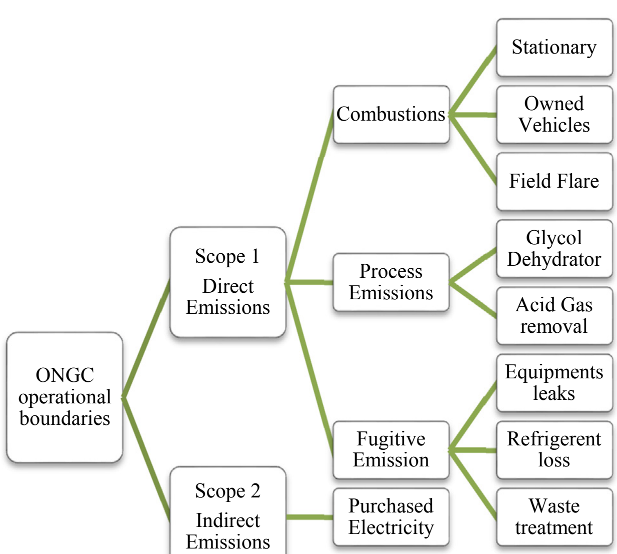


Fig. 5. Emission sources for GHG inventory and assessment.

fuel purchase invoices, equipment maintenance logs and from the reporting organization's Enterprise Resource Planning (ERP) software systems (www.ongcindia.com). After the data collection decision steps determines the technique for calculating the emissions.

The GHG Protocol and ISO 14064–1: 2006 standard has been followed for calculating GHG emission inventory, and technical inputs for calculation methodologies have been taken from the API Compendium. Generally, emissions from all sources have been computed by multiplying activity data with the relevant corresponding emission factor. A sample step based decision flow chart has been adopted to determine the technique for calculating emissions from a flare in an O&G sector, depending upon the data available within the reporting organization (API, 2009). The ISO-14064 clearly explicates both scopes, with improved transparency as defined for GHG accounting and reporting standards using GHG Protocol.

Several free online-software has also been developed for the imaginary enterprise for basic GHG quantification on the GHG protocol philosophy. However, the GHG accounting is based on the scope of emissions, which differs between organizations, the validity, and reliability of the studies are partly compared and relatively low respectively. However, the free online tools suggest an essential awareness for companies (Harangozo and Szigeti, 2018).

Accordingly, the real data collection has been collected for year-long study and GHG assessment study has been carried out for 420 + sites. The baseline year for the study has been taken as 2015 and assessment year period 2016–2017.

2.3. Standard GHG assessment process

While most organizations keep records of the quantities of purchased fuels and purchased electricity, datasets for other emission sources are not available. In such cases, assumptions can be used, provided that these are clearly stated in the methodology.

Emission factors have been used for converting usage of sources of emission and incorporate into the corresponding GHG emissions (Bajpai and Gupta, 2007). The published papers provide the elements which are more reliable and accurate, and these factors has been utilised in this study. It has been recommended that GHG Protocol worksheets published by WRI and WBCSD shall be utilised for the calculation of Emission Factors (EF) (Howarth et al., 2011). However, if more up-to-date emission factors are available, those should be used with appropriate justification. The current inventory utilizes a mix of Emission Factor sources that are considered to be the most accurate and relevant to the respective emission source. The emission sources data and relevant emission factors being used in this GHG assessment has been summarised in Table 3 and Table 4. Various Life Cycle Analysis (LCA) strategical models has been also studied for GHG emissions for baseline GHG assessment for ONGC (Karman, 2007).

2.4. Process undertaken at ONGC

In O&G sector, direct measurement of GHG emissions by monitoring concentration of GHG in the output gas and gas flow rate has been preferred in the past. However, this method being extremely time intensive and costly and therefore, has not been utilized for the present work. Calculating GHG emissions using mass-balance approach is also possible, however, it is practically not feasible due to the numerous factors including variations in the compositions, flow rates of different streams and non-availability of continuous data (EPA, 2016; Office and March, 2017). The common practice in O&G industry has been reported to calculate CO_2 and CH_4 emissions only as major contributors for the GHG inventory.

Emphasis has been given for real data collection and its

Table 2
Industrial emissions sources and classifications as per GHG protocol and ISO standards.

Source at Industry	Description and relevance
Direct Emissions: Combustion, Flare, Fuel Consumption, Fugitive source, Refrigerant leaks, Wastewater treatment, Vent/Process emissions	
Captive Power Plants, Boilers/Steam generators, Backup Generators, Bath/Emulsion Heater Treaters, Gas Pumps	Consumption of fuel in equipment leads to GHG emissions, mainly CO_2 along with CH_4 and N_2O in minor quantities
Plant designed system	Flares are basically burning of flammable gas which is either commercially un-usable or may be released by pressure relief valves during unplanned over-pressuring of equipment. The flammable gas generally has high methane content and flaring combusts the gas to produce CO_2, a less potent GHG as compared to methane
Company owned vehicle	Regular field transportation leads to GHG emissions, mainly CO_2 along with CH_4 and N_2O in minor quantities
Leakage from equipment	A number of pressurized equipment that has the potential to leak including valves, flanges, pump seals, compressor seals, relief valves, sampling connections, process drains, open-ended pipelines and other miscellaneous component types. Equipment handling "live" crude or gas act as a source of GHG emissions as the leaked gas from these equipment has a high CH_4 and minor CO_2 content
Heating, Ventilating, and Air Conditioning (HVAC) systems	Stand-alone air conditioning equipment and chillers use HCFC-22 and HFC gases (HFC-134a, R-410A) as refrigerants. Emissions of HFC gases are included in a GHG inventory whereas emissions of HCFC-22 are excluded because it is an ozone depleting substance are governed under the Montreal Protocol(Hu et al., 2017)
Produced water from oil and gas wells (Fakhru'l-Razi et al., 2009)	O& G industries produce huge quantity of produced water which are re-utilised after biogenically treatment. During the treatment, emissions of CH_4 and CO_2 are being released under anaerobic or aerobic conditions respectively. Mostly wastewater disposed at sub-surface, so emissions are not accounted. In cases where wastewater has been treated aerobically, CO_2 emissions have been accounted
Glycol Dehydrator (GD) and Acid Gas Removal Systems (AGRS) (Roscioli et al., 2015)	GD has been used to remove water from gas streams by contacting the gas with a liquid glycol stream in an absorber. The liquid glycol absorbs the water from the gas stream, and the water is driven from the glycol by heating the glycol in the regenerator. AGRS units remove H_2S and CO_2 from sour gas by bringing it in contact with a liquid solution, typically containing amines. A regenerator is used to regenerate the absorber liquid. GHG emissions occur because the amine solution absorbs a small amount of CH_4 from the gas, which is then released to the atmosphere during regeneration. In some systems, regenerator vent is directed to a flare and venting of CH_4 is prevented.
Indirect Emissions: Purchased electricity from the grid	
Derived from Electricity bills	CO_2 Emissions due to purchase of electricity from the National Grid are included as the electricity is generated through consumption of fossil fuels which lead to GHG emissions.

Table 3
Data collection from various emission sources and assumptions.

Emission Source	Data Required (Unit)	Data Source	Assumptions for activity data
Stationary sources fuel consumption	Fuel quantity in (Litres)	Log books records Financial statements	The quantity of fuel consumed is calculated as: FB = FP + (FSS − FSE) where: FB and FP represents, Fuel Burned and Fuel Purchased during reporting period respectively. Further, FSS and FSE reflects Fuel Stock at Start and Fuel Stock at End For the purpose of simplification, fuel burned has been assumed to be equal to fuel purchased in the reporting period
Flare	Quantity of gas flared (SCM)	SCADA system	Flare combustion efficiency has been assumed as 98%. Supervisory Control and Data Acquisition (SCADA) continuously stores the required data.
	Molar composition of flare gas	Gas composition regular testing	Gas composition is assumed as representative of the composition for all times throughout the reporting period. If molar composition is not provided, flare gas is assumed to have same characteristics as that of Natural Gas(NG)
Gas leak from	Gas / Crude throughput (Barrel MMSCF)	Pressurized equipment	Facility level Emission factors from API Compendium
Treatment of wastewater	Volume (SCM) BOD (kg BOD/m^3)	Utilities log sheets Periodic testing	Biochemical Oxygen Demand(BOD)
Grid electricity	Purchased electricity (kWh)	Grid electricity billing cycle	Electricity secured through wheeling of power from Captive Power Plants (CPP) is not considered.

methodology varies for different sources for various emission sources. This improves the estimation reliability and signifies for futuristic plans to combat the emissions (USA, 2010).

The clear distinction has been related for direct and indirect emissions for onshore and offshore O&G operations. In general, direct emissions are related to the processes of production, transport and combustion of the fuel along its life-cycle, while indirect emissions are related to economic, geopolitical or behavioural factors not directly related to the aforementioned processes (Harangozo and Szigeti, 2018).

The estimation of GHG emissions have been given a second thought using various other methodological aspects using two different macro-economic models like OPGEE (El-Houjeiri et al., 2013), and GREET (Keesom et al., 2009). These models have been derived based on one basic concept of fuel life cycle. The conventional and unconventional O&G pathways, processes and technologies have been studied for describing engineering and technological aspects of exploration, production and extraction.

For ONGC specific case, individual site visits, specific data collection and data compilation has been conducted and prepared a business case for the appraisal and approval of organizational top management. Government regulations and various other organizational policies and guidelines have been included for the business case (Remme et al., 2012).

Table 4
Estimation of Emission Factors for different sources.

Emission Source	Input parameters	Expression of Emission Factor (EF) (API, 2009)
Emission Sources: Scope 1 Fuel Consumption	Net Calorific Value Carbon Content values (mass and volume terms)	$EF_M = (EF_E*NCV)/10^6$ and $EF_V = (EF_E)/(10^6*D)$ where: EF_M = Emission Factor based on mass (kg GHG/kg fuel) EF_E = Emission Factor based on energy (kg GHG/TJ of energy) NCV = Net Calorific Value of fuel (TJ/kg of fuel) EF_V = Emission Factor based on volume (kg GHG/litre fuel or kg GHG/m^3 of fuel) D = Density of fuel (kg/m^3) = 0.84 kg/litre EF_E = 74,100 kg CO_2/TJ as per Column C for "Gas/Diesel Oil" of 2006 IPCC Guidelines GHG Inventories NCV = 43.0 TJ/kg of Fuel as per Column B for "Gas/Diesel Oil" of 2006 IPCC Guidelines GHG Inventories
Flare	molar composition of flare gas	$E(CO_2) = (V_f*1000*\%C*44)/23.685$ Where $E(CO_2)$ = CO_2 Emissions (in tonnes), V_f = Volume of flare gas (in metric million standard cubic feet) %C= Molar % of Carbon in the flare gas and factor for conversion of Carbon to CO_2 = 44 Factor for converting volume of gas into molar weight = 23.685 $\%C = [(\%C_1 + 2*\%C_2 + 3*\%C_3 + 4*\%C_4 + 5*\%C_5*0.98) + \%CO_2]$ where: %C-C5% = Molar % of Carbon, Methane, Ethane, Propane, Butane, Pentane in the flare gas respectively. $\%CO_2$= Molar % of Carbon dioxide in the flare gas/Factor flare combustion efficiency of = 0.98
Incomplete combustion	Methane outlook	$E(CH_4) = (V_f*1000*\ \%C_1*0.02)/23.685$ Where: E (CH_4) = CH_4 Emissions (in tonnes), V_f = Volume of flare gas (in in metric million standard cubic feet) %C1= Molar % of Methane in the flare gas, Conversion factor of Carbon to CH_4 = 0.02 Factor to account for remaining methane of 2% due to flare efficiency of 98% = 0.02 Factor for converting volume of gas into molar weight = 23.685 $E(CO_2) = \left(V_{ww}*\frac{BOD_5}{7}*\frac{44}{32}*10^{-9}\right)$
Treatment of wastewater		Where: $E(CO_2)$ = Emission of CO_2 (in tonnes), V_{WW} = Volume of wastewater in litres/annum $BOD_5/7$ = Approximation of ultimate BOD (mg/L), 44/32 = Conversion factor for Oxygen to CO_2
Emission equipment leaks	Relative concentration of CH_4	Facility level average emission factors of the API Compendium are utilized for oil and gas emissions calculation. For example, for an onshore oil production facility, the methane emission factor is $2.346*10^{-4}$ tonnes CH_4/barrel (bbl) produced. The default methane concentration used is 78.8%
Emission Sources: Scope 2 Electricity purchased from Grid		EF for electricity purchased from the national grid in India is published by the Central Electricity Authority (CEA) India. These emission factors have been determined in accordance with UNFCCC Clean Development Mechanism (CDM) Methodological Tool titled "Tool to calculate the emission factor for an electricity system"

ONGC too have considered that a more efficient and targeted approach has been required focused on accurate documentation and steps. These steps closely relates to the subject addressed in the present study and considering their reliability and their significance on the topics for the potential mitigation projects in ONGC and future reader.

A comprehensive process chain has been undertaken at ONGC as shown in Fig. 6 for GHG identification and its mitigation opportunities. The GHG footprint study has reflected the two-way interlinkage between wide supply-chain of the organization like ONGC. This bi-directional linkage has been helpful to motivate organizational employees, improves the brand image and adopting new technologies.

3. Findings and results: GHG assessment

General industry practice is to calculate CO_2 and CH_4 emissions only for maximum contribution to the GHG inventory. However, to present much closer accurate GHG inventory, emissions have been quantified with Nitrous Oxide (N_2O) too. The CO_2 equivalent emissions have been calculated by summing the weighted contribution of each GHG wherein the weighted contribution of each GHG is calculated by multiplying the emissions of a GHG by its corresponding GWP (API, 2009).

$$Emissions\ (CO_{2e}) = (Emissions_{CO_2} \cdot GWP_{CO_2}) + (Emissions_{CH_4} \cdot GWP_{CH_4}) + (Emissions_{N_2O} \cdot GWP_{N_2O})$$

ONGC's 420 + installation sites have been divided into many work-centre, and each have been classified for the analysis of GHG emissions. Since the data of emissions for each work-centre has found very exhaustive, and categorizes the emissions (tonnes CO_2e) from work centre classified in offshore, onshore, oil/gas processing plants and few office centres. Based on the activity data and results, the importance of work centre on the carbon emissions has been projected and suggested the GHG mitigation opportunities for the related work centre. For the assessment period, the overall GHG emission footprint for E&P operations has estimated approximately nine million tonnes CO_2e and Table 5 shows the total as well as source wise breakup of GHG inventory. As can be seen from Table 5, GHG emissions due to stationary combustion has been found the highest, accounting for more than half (55%) of overall emissions. Fugitive emissions due to leakage of gas account for around 19% of the total emissions and in addition to 18% contribution due to flaring phenomenon in O&G sector. The role of glycol dehydrator and acid gas removal units in the gas processing complex are accountable for approximately 6% of emissions generated by processes. Electricity purchased from the grid contributes the

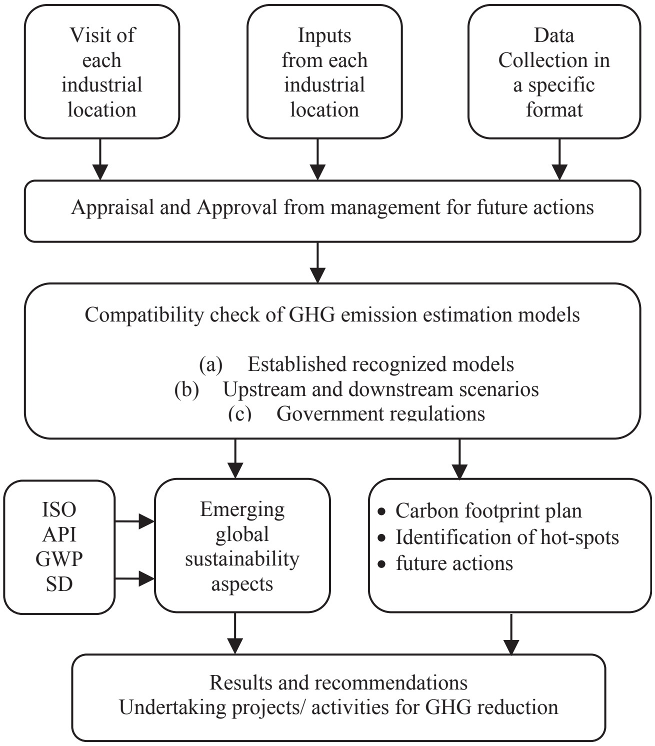


Fig. 6. Process adopted at ONGC India.

remaining 2%. Fig. 7 provides a further breakup of emission sources as (a), (b), (c) and (d). It reflects that stationary combustion emission is being generated by consumption of natural gas in captive power plants, bath heaters, heater treaters and other equipment. The stationary combustion emissions account for approximately 91% of total emission.

Consumption of diesel has been reported as 9% of total stationary fuel consumption sources. Fugitive emissions have been a surprise with 45%, one of the majority emission contributions from major Oil processing facilities (45%) whereas gas production facilities have comparatively lower fugitive emissions (16%). With another fact, gas processing facilities contribute at much higher percentage fugitive emission (38%). Emissions from pipeline leaks, leakage of refrigerant and treatment of wastewater contribute negligibly.

As shown in Tables 5 and 6, approximately 50% of emissions are contributed by the offshore work-centre and 27% from all onshore operations. Critical 22% of the emissions have been added by two oil/gas processing plants 1 and 2. Further analysis of GHG emissions suggested 12–14% of emissions due to flaring of natural gas at offshore and onshore installations and equivalent 1,722,192 tonnes of CO_2.

Fugitive emissions has been also calculated by multiplying facility throughput with default site emission factors results in emissions of 390,000 tonnes CO_2 equivalent, approximately 12% of overall emissions. Around 1% of the emissions are due to consumption of 2.3 million litres of aviation fuel for running of helicopter services too.

It has been also shown in Fig. 8 (a) and (b) that plants 1 and 2 are the significant contributors to CO_2 emissions, generating around 1.33 million and 1.03 million tonnes CO_2e emissions respectively. The primary sources of emissions at both plants include consumption of natural gas, emissions from fugitive emissions and emissions from processes. A significant contribution to higher emissions at the plant 1 is due to emissions from the acid gas removal process, which accounts for approximately 300,000 tonnes higher than at plant 2 due to much higher quantity of gas processing at the plant 1. On the other side, onshore work-centres in the western part of the country and northeast part are further contributors of the carbon emissions due to significant consumption of natural gas and diesel consumption.

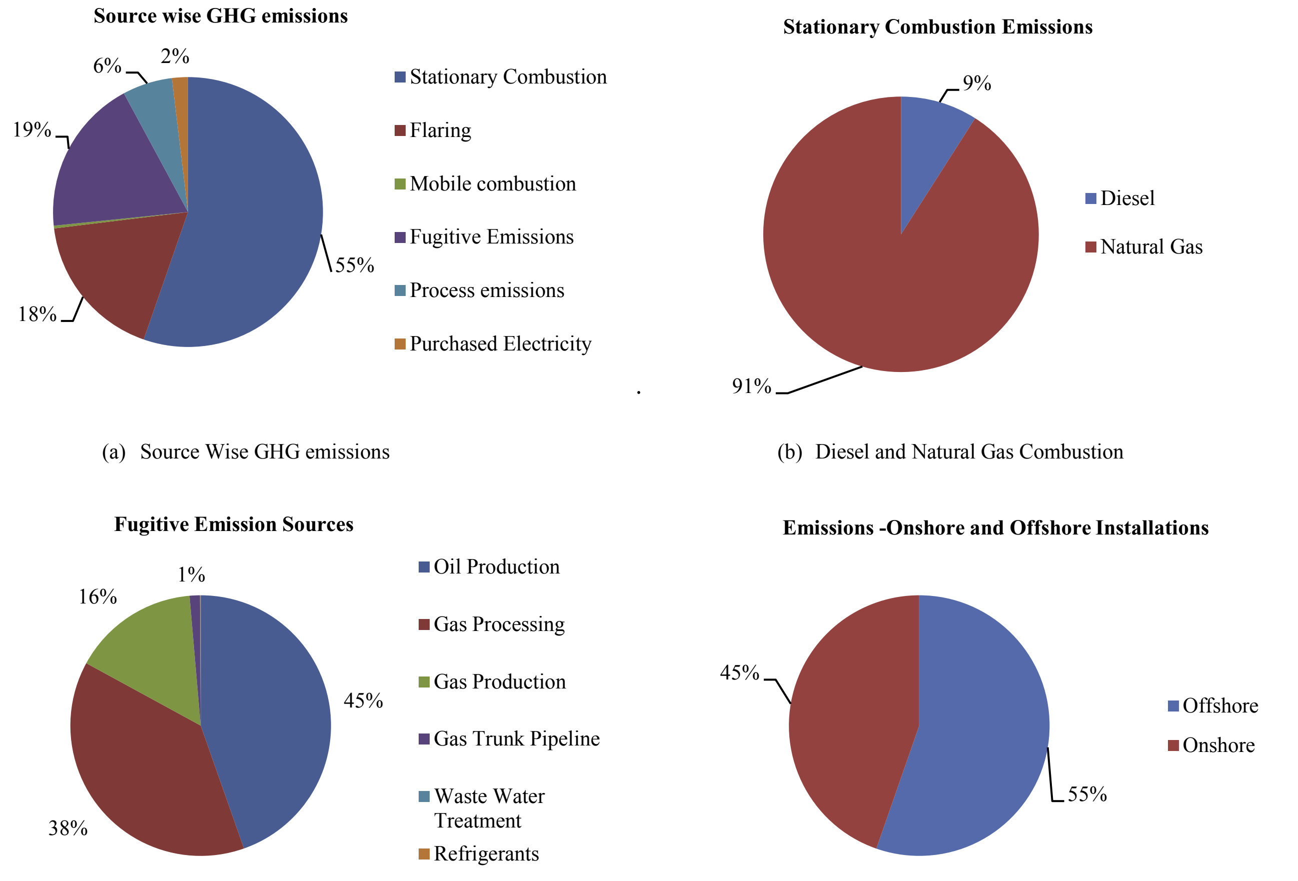
GHG intensity relates to organizational target specified to reduce the emissions on the account of productivity and economic performance. On the other side, emission target or intensity specifies the measured emission reduction in metric tons relative to the baseline data. Emission Intensity (EI) reflects on the amount of energy used per unit of Gross Domestic Product (GDP) at national level and further on fuel mix expressed as CO_2 per BTU or joule (Herzog and Baumert, 2006).

EI has been used to track the GHG impact of a company over a period of years, especially in cases where a company experiences organic growth and corresponding growth in its emissions. In such case, reduction in GHG emissions per unit of a factor (e.g. product output, number of employees, company turnover) can demonstrate the commitment to reduce its GHG impact. For the reporting period Table 6 give overall emissions and relative intensity of GHG emissions.

By comparing its GHG emission profile with its peers and competitors, an organization can also evaluate how it stands concerning managing GHG emissions from its operations. Since different organizations have different scales of operations, comparing actual GHG emissions does not provide meaningful insights. Therefore, comparisons need to be made from emission intensity estimates that can provide a normalized correlation between different global organizations. Fig. 9 compares the GHG emissions of global peers and competitors during the assessment period. Exxon USA and BP UK mainly contributes normalized GHG emissions from process activities and primarily offset the emissions by the operational improvement. Shell has been using GWP assessment report of IPCC for GHG assessment since 2015 and comparing the emissions impact with equivalent CO_2. The company has shown a favourable decrease in GHG emissions mainly only the

Table 5
GHG Inventory for ONGC pan India for direct and indirect emissions.

Scope	CO_2 (tonnes)	CH_4 (tonnes)	N_2O (tonnes)	Total CO_2e (Tonnes)	% of total emissions	Intensity (kg CO_2e/Mtoe produced)
Scope 1 – Direct Emissions						
Stationary Combustion	5,358,389	500	13	5,372,791	55.32	103.20
Flaring	1,603,441	5655	0	1,722,192	17.73	33.08
Mobile combustion	31,321	4	0	31,511	0.32	0.61
Fugitive Emissions	1555	86,570	0	1,819,521	18.74	34.95
Process Emission	576,362	170	0	579,940	5.97	11.14
Scope 1 Total	7,571,068	92,898	13	9,525,955	98.09	182.98
Scope 2 – Energy indirect Emissions						
Purchased Electricity	185,516	0	0	185,516	1.91	3.56
Total Emissions	7,756,585	92,898	13	9,711,471	100.00%	186.54



(a) Source Wise GHG emissions

(b) Diesel and Natural Gas Combustion

(c) Fugitive Emissions Sources

(d) Comparison between Offshore and Onshore Emissions

Fig. 7. Emission sources and different four scenarios (a) Source wise, (b) Fuel type, (c) Fugitive and (d) Site specific.

Table 6
Emissions data from different sources (in tonnes) and their percentage contribution.

Work center	Diesel	Natural Gas	Flare	Vehicle	Fugitive Emission	Process Emission	Grid Electricity	Total	Percentage Contribution (%)
Offshore Installation	286,762	3,095,537	1,376,439	12,710	590,676	0	12,265	5,374,389	50.58
Onshore Installation	196,488	1,791,224	333,727	13,424	373,875	0	160,204	2,868,942	27
Plants	114	910,971	12,024	663	854,979	579,940	5884	2,365,575	22.26
Offices	2662	0	0	4715	0	0	7165	14,542	0.13
Grand Total	486,026	5,797,732	1,722,190	31,512	1,819,530	579,940	185,518	10,623,448	100.00

account of flaring and carbon capture and storage (CCS) activities.

On the other side, each year, the International Association of Oil and Gas Producers (IOGP) have been collecting environmental data from member companies (IPIECA et al., 2011). The data analysis allows member companies to compare their performance and lead the sector with higher efficient performance. Gaseous emission, flaring, aqueous discharges, drilling fluid, spillage and freshwater exploitation have been identified as major Environmental indicators.

It has been concluded that India and specifically ONGC is at modest level of GHG emission intensity, and GHG mitigation opportunities have given a way forward.

4. GHG mitigation case studies

ONGC had started the mitigation and adaptation plans starting with several innovative Clean Development Mechanism (CDM) projects on the concept of flared gas reduction and Waste Heat Recovery (WHR) (Shackley and Verma, 2008; Singh et al., 2017).

Fugitive emissions have been also targeted through a voluntary participation with Global Methane Initiative (GMI) in collaboration with United States Environmental Protection Agency (USEPA) (Emissions and Recovery, 2011). Through GMI another cross-organizational fugitive emissions leak detection survey has been conducted using FLIR™ Infrared camera(Chakraborty et al., 2012). The detailed inventory has been prepared for few onshore and offshore O&G installations. Several other focuses has been given on the active implementation of solar Photo-Voltaic (PV) based set-ups for roof top office buildings. This transformation with RE sources has led to the status of 'Energy Company' in place of traditional 'Exploration and Production (E&P)' profile.

Two major research activities have been attempted usefully to mitigate the carbon emission, as Concentrated Solar Power (CSP) based solar thermal technology for crude oil heating and other bio-

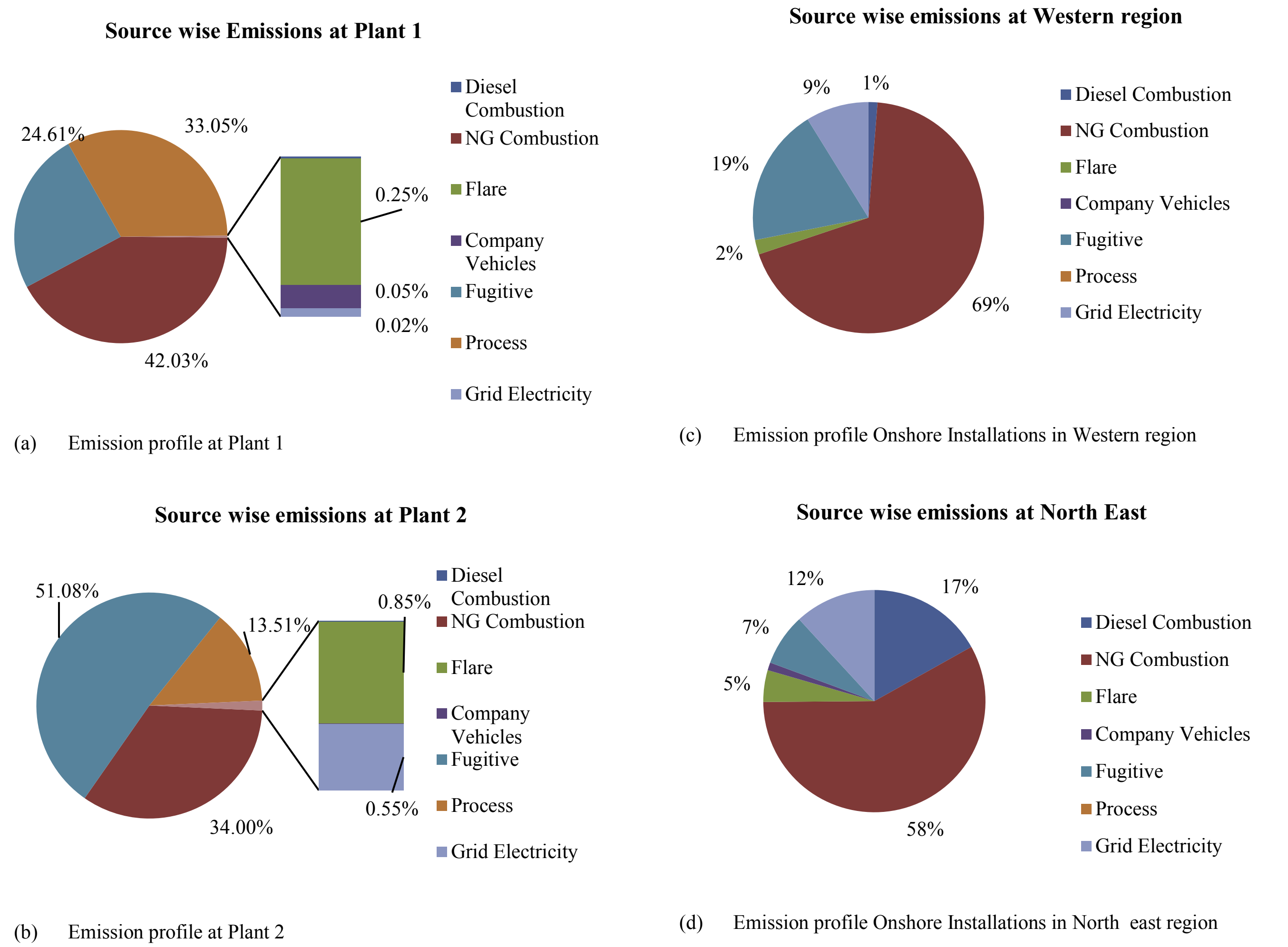


Fig. 8. Source wise emissions at Plants 1 and and Onshore (Western and North East) installations.

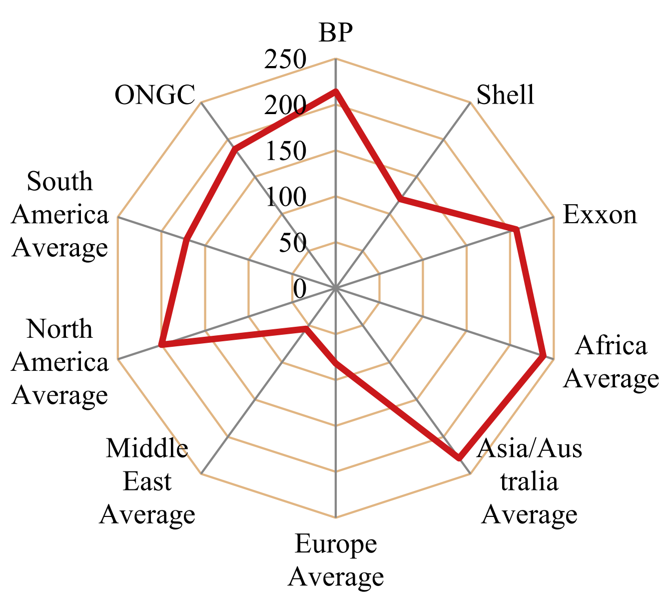


Fig. 9. Peer comparison for Emission Intensity.

fixation of industrial vent utilising the Microalgae bio-technology (Wang et al., 2008). The basic concept of these case studies has been summarised in this section.

(a) CSP based crude oil heating

The extracted crude oil from earth crust commonly termed as ‘Emulsion’ is being processed to separate from various mixture and contamination. Emulsions need heating at the first stage of crude oil processing using designed heater treater chambers and thick-oil loses their bonding.

Low temperature (25 ≈ 250 °C) industrial process is often used across multisector applications. The Solar Thermal energy in the lower temperature range supports these industrial processes and supports the green environment (Schnitzer et al., 2007). CSP based solar thermal technology is one of the models to research and investigate for economic viable solution in Oil and Gas industry.

This case study has been attempted for the substitution of natural gas being utilised for traditional heating with CSP based thermal heat. Any typical Group Gathering System (GGS) of O&G facility has been selected as the research platform (Choudhary et al., 2017). The heating of crude oil decreases the viscosity of oil which reduces the resistance flow of crude oil. The heater treater process system also separates the crude oil from various contaminations like sand, silt and water. This process includes pre-heating of the emulsion and overall repeats toward the separation of oil and water. The pre-heat temperature required at Heater Treater is in the range of 80–85 °C in Indian environmental conditions.

The novel solar assisted crude heater system has been studied for its potential to reduce natural gas consumption and associated emissions. The project replications lead to the estimated cost saving of 76 million dollars to CO_2e.

(b) Microalgae based carbon capture

The gaining interest of global society on bioenergy development has been also focused on energy mix, which is as preparatory for decision making in industries. At one of the industrial gas processing plant of ONGC, around 43 million cubic meters per day of sour gas is being received from its offshore fields, containing 150 ppm of H_2S (Garg and K, 1991). This sour gas is sweetened through other process and the H_2S concentration is brought down to less than 4 ppm. Separated sour gas is taken out with other associated processing machinery and finally the industrial vent released in the atmosphere. The vent gas contains on an average 23% CO_2, 15% O_2 and 60% N_2 water vapour and traces of hydrogen sulphide (Kumar, 2017).

The vent gas containing CO_2 has been targeted for biological sequestration and its conversion to valued added products by combination of algal biomass and anaerobic digestion for biogas generation. The vent gas analysis and pilot study was carried out for the period of six months and finally suggested that carbonation column is able to bring down 33% initial CO_2 concentration to an average of 15% CO_2 concentration (Yadav et al., 2016).

The biogas generated has been utilized for combustion purpose and substitute the NG being used for the crude oil heating. The present crude oil heating arrangement needs some electrical power requirements and to continue with the carbon sequestration, artificial lighting equipments has been utilized and the heating has been conducted for longer period of day and night time.

Both the concepts of utilising CSP module and bio-fixation has been proposed for integrated for crude oil heating and associated energy requirement as shown in Fig. 10. A techno-commercial study determined its cost-effective implementation at gas processing complex to fix environmental carbon and utilise value added products.

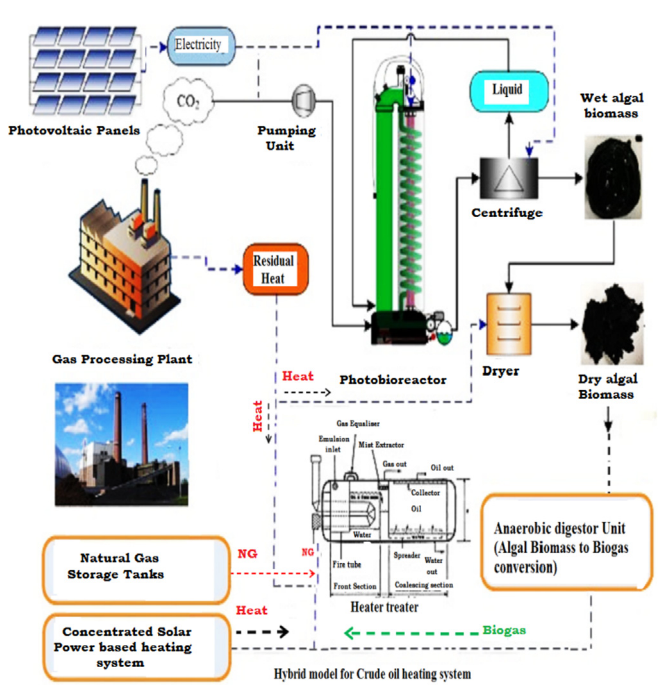


Fig. 10. Schematic crude oil heating hybrid system.

The research studies concludes that the application of bio-energy and solar-energy for the 'crude oil heating' in the oil and gas industry presents a very good business opportunities for the renewable energy industries too.

5. Future opportunities

The Netherlands environment assessment agency studied that during the year 2016, the overall global CO_2 emissions remained static and the GHG emission is at the level of 49.3 giga-tonnes of CO_2. This report also suggests that GHG emissions from India have registered around 6.4% increase. This increase has been emerged as a wake-up call for India, having a significant increase in the emissions (ICCT, 2010). The future opportunities need to be understood by India and ONGC based on this GHG accounting and major socio-political-environmental-legal policies prevailing globally.

India's climate change policies are being oriented towards non-fossil fuel vehicle by 2030, and it could over-achieve the emissions intensity target in line with Paris Agreement 2015 (Kumar, 2017). However, the need of energy security of India would promote to expand its domestic fossil fuel production, which could lead further GHG emissions. The Nationally Determined Contribution (NDC) of India puts the target for 2030 and to lower the carbon emissions intensity GDP by between 33% and 35% from 2005 levels (Robiou Du Pont et al., 2017). During the period between year 2014–2030 with current RE policies, it has been estimated that the average growth rate for solar and wind power generation is around 3% about half the growth rate of overall electricity production.

In another reporting from Carbon Disclosure Project (CDP), more than 40 Indian stock exchange companies are working on the GHG inventory and increasing focus on reduction of emission (Huang et al., 2009). The renewable energy targets are being set up beside an internal price on carbon concerning risk mitigation strategies. Recently, the Indian government announced Bharat Stage-VI guidelines on vehicular emissions standards to be implemented by the year 2020, which would impact the O&G sector. The Bureau of Energy Efficiency (BEE) and Ministry of Power also focusing on widening stringent standards for O&G sector under running scheme of the Perform Achieve and Trade (PAT) (Chandel et al., 2016; Osmani, 2017). These cumulatively and critical guidelines put Indian corporate industries for the more proactive role in mitigating and adapting to emissions. In response, the multi-sectoral business has been focused on low carbon economy and various initiatives of energy labelling, audits, energy efficiency and CDM projects have translated to 28 million tons of certified CO_2 emissions reductions.

The GHG quantification studies also reported for strategies for carbon reduction too and termed as Carbon offsetting, which refers to carbon finance mechanism to neutralize the footprint (Harangozo and Szigeti, 2018). A Measureable, Reportable, and Verifiable (MRV) modeling has been emerged in Thailand for performance track on account of GHG mitigation. These performance check and balance has been acknowledged by scheme of Emission Trading System (ETS) (Usapein and Chavalparit, 2017).

Environmentally conscious business decisions would allow organization leapfrog into carbon-efficient advanced technologies era. These initiatives need significant attention in power or energy sector with cleaner market as well as Research & Development for new climate-friendly technologies.

In this regard, the identifications of mitigation opportunities have been derived from ONGC's GHG inventory and business work process. An effort has been made to analyse potential GHG reduction of identified opportunities and whether they can be implemented using benefits from Kyoto's Clean Development

Mechanism (CDM) (Sanaeepur et al., 2014).

The increasing cost of natural resources and various incentives on renewable sources implementation, the task of GHG mitigation is expected for undoubtedly rise. In this way, not only the company will be future ready for any renewable energy-related regulation with operations, but also stand to gain financially. The brand value of the organization would be additional benefit in the global arena.

Based on comprehensive discussions and results derived from this study, a detailed analysis has been prepared and proposed the various GHG mitigation projects in the O&G sector and specifically for ONGC as elaborated in Table 7. Table 7 describes the opportunity for ONGC on their GHG reduction potential, CDM potential and the industrial sites where the opportunities could be implemented. Since prospects are similar across various industrial sites an assessment for common opportunities is provided.

Detailed analysis of industrial process linked associated carbon emissions are to be analysed and attention is to be paid for novel RE technologies, Carbon Capture and Storage Solution, Energy efficiency, Energy storage and Safety solution. As government of India move towards market pricing of Natural Gas and Diesel, each small gain from these projects today will lead to high benefits tomorrow once pricing of Natural Resources is allowed to track their global prices.

In the economic scenario, when carbon pricing is emerging, significant life–cycle analysis of emissions to be studied to outside the legislative compliance of GHG mitigations regulations. With these bright signs, ONGC has adopted the approach for low carbon economy and contributing to Indian GDP.

The worldwide energy industries are on a turning point because of the emergence of low carbon fuel investments. Various studies projected that hydrocarbons would still dominate the future energy requirement in the range of 60% of global energy need till 2035.

The GHG assessment started voluntary in India and ONGC being major contributor of energy demand, took the lead and reported the overall pan India GHG assessment.

6. Conclusions

Stakeholders from community perceive the catastrophic challenges due to climate change, business and governmental institutions globally and now these challenges are part of sustainable development. The global problems are being thought with local solutions in respective industry. The developed countries and also fast-growing developing countries as China and India are working exhaustively with energy synchronization and policies.

GHG assessment of ONGC has shown the major GHG contribution has been from stationary fuel combustion and accounts for more than half (55%) of overall emissions. Fugitive emissions due to leakage of gas from pressurized equipment, loss of refrigerant and treatment of wastewater contribute to 19% of the emissions. Another 18% of emissions are added by flaring. 6% of emissions are added by processes including glycol dehydrator and acid gas removal units while electricity purchased from the grid contributes the remaining 2%.

API, ISO, WRI and WBCSD have been major reference documents for data collection and further their analysis. The emission factors of API are instrumental for the GHG estimation. The importance of an organizational boundary defined by ISO is must for accurate assessment.

Voluntary and mandatory guidelines have been driving force behind the reporting and accounting and imbibing the brand values within this giant energy anchor of the country. Forecasting the

Table 7
List of GHG mitigation opportunities in ONGC.

Sl. No	Description of the opportunity	GHG reduction potential in tonnes CO_2	CDM potential	Potential Industrial location and Installations
Waste Heat Recovery (WHR) & Energy Efficiency (EE)				
1	WHR from Process Gas Compressors (PGC)	87,750	Yes	The WHR potential exists at all PGCs installed at offshore locations. The opportunity to implement preheating the crude/gas before entering the main turbine
2	Inlet air cooling of Gas Turbines (GT)	28,976	Yes	Major modification of existing facilities at Offshore
3	WHR at Gas Turbine	5600	Yes	Captive Power Plants at six onshore locations. 10–22% improvement has estimated if the technology is implemented
4	WHR from Diesel Generator sets	250 tonne CO_2 per ORC	Yes	Installation of Organic Rankine Cycle (ORC) turbines to utilize WHR at onshore drilling rigs
Flaring Reduction				
5	Flaring reduction	5,01,037 (Offshore) & 1,20,000 (Onshore)	Yes	Sites in Offshore and Onshore (The GHG potential is given in tonnes for offshore and onshore)
Fugitive Emissions Management				
6	On site equipments	Quantify the emissions	No	Offshore and Onshore
7	Gas Pneumatic Controls	–	Yes	Conversion of gas pneumatic controls to instrument air devices at all offshore and onshore
8	Vapour Recovery unit	6 kg CO_2 per 100 SCM of gas recovered	Yes	High fugitive emissions sites at GGS and both Plants 1 and 2
Improving Motor Management				
9	Motors	No	No	Onshore and offshore production sites
10	MOIL pump resizing	8760	Yes	Offshore production sites
Renewable Resources utilisation				
11	Office lighting	6000	Yes	Major onshore production sites
12	Roof tops	19,867	Yes	Solar PV roof tops of selected location and outdoor lighting at onshore sites
13	Power Plants	2,13,872	Yes	Large scale Concentrated Solar Plants at three major onshore sites
14	Carbon capture	32,786	Yes	Utilisation of Microalgae Biomass for Gas processing Complex
15	Crude oil heating	2,87,120	Yes	Utilising Hybrid solution with Biogas and Solar Power (PV and CSP) for major Onshore production sites and Gas processing complex

policies and stringent conditions on various industrial sectors, it is expected that Indian regulations would be mandatory for GHG assessment in the future. Oil and Gas companies perceive risen pressure to de-risk their existing portfolio and diversifications, but the pace of transition from traditional to green energy is the critical factor in today's era.

Fugitive emissions have been playing a greater impact on the industrial process, which has been targeted as improvement opportunities as well as safety aspects of work place. This comprehensive study is expected to play an important role in successful implementation of many of the GHG opportunities suggested, as compared with two case studies discussed. This research is expected to benefits few of the developing countries of similar demography for identification as well as reduction of GHG. Further, to improve the GHG data, uncertainty of direct and indirect sources needs longer time duration analysis.

Authors contribution

Piyush Choudhary Contributions for the paper: Drafting original concept, Importance of Sustainable Development, Roles Investigation, Methodology, Visualization, Writing, review, editing and finalisation.

Rakesh Kumar Srivastava Contribution for the paper: Suggestion aspect, control methodology, visualisation and innovative strategy, Project administration, Supervision, Validation, review & editing

Somnath De Contribution for the paper: Importance of Sustainability in Indian Context as well as global perspectives. Role of RE sources for Oil Industry. He holds very strong background in the field of Carbon Mitigation and Adaptation programmes of Government of India.

Conflicts of interest

The authors declare that they have no conflict of interest.

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